Both the Porte et al. paper and the preset application describe methods for electric orbit raising (EOR) of geosynchronous satellites using electric propulsion (EP). The differences between disclosures of the Porte et al. paper and the presently pending Claims are highlighted with reference to the following paragraph:

The Porte et al. paper at page 2, column 2, paragraph 3 of section 3.2 recites:

"*(1)* In order to cope with the high power requirements of EP, the solar arrays must be fully deployed and permanently oriented towards the sun. *(2)* The spacecraft must also orient the thruster along its velocity. *(3)* The only flight configuration compatible with these two requirements is a three axis configuration with the solar array rotation axis aligned with the orbit normal. *(4)* The only degree of freedom with respect to the operational configuration is possibly the choice of the earth facing panel (+/- Z or +/- X)."

With regard to sentence *(1)*, both the Porte et al. paper and the present inventors recognize the need to provide sufficient power to run the EP mission. Porte et al. use the term "oriented towards the sun" to describe the attitude of the solar arrays. In the remainder of section 3.2, Porte et al. describe how to obtain sufficient power to run the electric propulsion subsystem (EPS) and requires that "the full BOL SA performance is used" (page 3, column 2, paragraph 2 where BOL = Beginning of Life and SA = Solar array). Since full performance is needed the implication is that "oriented towards the sun," means normal to the sun, though Porte never states that as a requirement.

The present application discloses that the *desired* optimal thrust direction can have large in-plane and out-of-plane magnitudes and variations over an individual orbit and still larger variations over the many days of electric orbit raising (EOR). These large variations are seen in Figs. 8 and 9 of the present application, which have been amended for the purposes of this response to show the magnitudes of the angles (copies enclosed). The preferred spacecraft attitude has the solar array rotation axis normal to the sun line. The present application discloses methods for pointing the thruster in any direction while keeping the sun normal to the solar arrays (not just oriented towards the sun) to meet the high power requirements of electric propulsion.

not true

As described below, the attitude restrictions placed by Porte et al. preclude the solar arrays from being normal or even adequately oriented towards the sun except when the thrusting direction is severely restricted.

not in claims

With regard to sentence *(2)*, Porte et al. restrict the thruster to be oriented along the velocity direction. The present application discloses that for efficient orbital transfers the in-plane component of thrust is generally not oriented along the spacecraft's velocity (see, for example, Figs 7 and 8 of the present application). At times, the desired thrust could be near the velocity direction but at other times it may be desirable to thrust opposite to the velocity direction and at still other times it may even be desirable to thrust nearly normal to the velocity direction. The restriction that the thruster orient along the velocity (in-plane) is inefficient for transfer to geosynchronous orbit from an elliptical orbit with or without inclination change.

With regard to sentence *(3)*, this statement, central to the Porte et al. disclosure is, in general, incorrect. It is only correct in the very restrictive case when the sun's direction is in the orbit plane (which cannot be maintained over the entire EOR duration).

Porte et al. fail to explicitly state restrictions placed on the spacecraft attitude during continuous EOR firing. Though unstated in et al., sentence *(3)* implies that the thruster is aligned on the spacecraft body normal to the rotation axis of the solar array (a necessity for delivering thrust along the velocity when the solar array rotation axis is aligned with the orbit normal). But later in the paper Porte et al. disclose that in all strategies "The in-plane component is normal to the earth direction, assuming that the attitude reference is provided by the IRES with limited bias capability" (Strategy 3, page 6, column 1, section 3.4.3, paragraph 1).

In these restricted circumstances the solar array can be kept oriented towards the sun but not, in general, in its preferred orientation *normal* to the sun during an EOR mission duration of hundreds of days.

Furthermore, Porte et al. later disclose slewing the EPS orientation out-of-plane "about the earth direction around the orbit nodes" to change inclination (Strategy 2, page 5, column 2, paragraph 1). Porte et al. say that for both Strategies 2 and 3 "the required normal (to the orbit plane) thrust components are obtained by rotating the spacecraft around the earth/satellite direction" (Strategy 2, page 2, column 1, section 3.1, paragraph 5 and Strategy 3, page 6, section 3.4.3, paragraph 1). As this *spacecraft* rotation occurs the solar array rotation axis will move away from being aligned with the orbit normal and consequently the solar arrays will move further from being permanently oriented towards the sun but this contingency is not addressed by Porte et al. For significant inclination change requiring large slewing angles the orientation of the solar arrays may be very far off the normal to the sun line and there will be insufficient power to run the electric propulsion thrusters.

The present application discloses a method of steering that permits the solar array rotation axis to be very far from normal to the orbit but still have the solar array rotation axis normal to the sun line for maximum power generation. The optimal in-plane thrust direction is not even constrained to be along the velocity direction.

Instead of rotating around the earth-satellite direction (Porte et al.) the present application describes a rotation around the desired direction of thrust. First, orient the thruster(s) along the desired thrust direction. Then, rotate the spacecraft around this direction until the solar array rotation axis is aligned to be normal to the sun line. Lastly, rotate the solar arrays in azimuth around the solar array rotation axis until they are oriented towards the sun for maximum power generation. The present application describes this process when the electric thruster alignment is such that the thrust vector is not necessarily normal to the rotation axis of the solar arrays.

With regard to sentence *(4)*, this statement highlights the very restrictive assumptions of Porte et al. on spacecraft and thrust orientation. Although sentence *(2)* states that the spacecraft must "orient the thruster along the velocity" the elliptical orbit of Strategy 3 (preferred by Porte et al.) makes that impossible. That is why in all Porte et al. strategies "The in-plane component is

normal to the earth direction, assuming that the attitude reference is provided by the IRES with limited bias capability" (Strategy 3, page 6, column 1, section 3.4.3, paragraph 1).

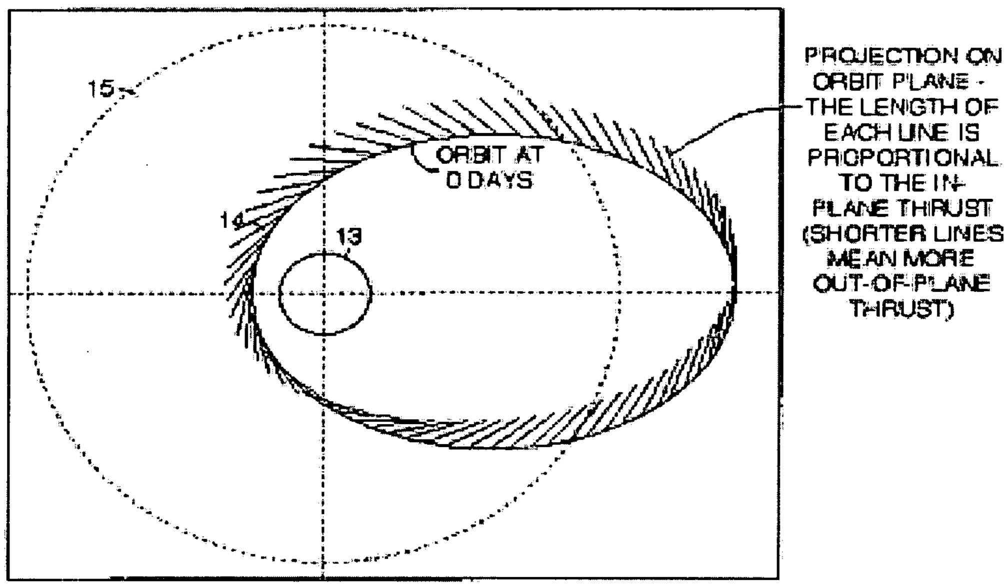
In fact, the present application discloses that the *desired* in-plane component of thrust is not generally normal to the earth direction nor is it along the velocity direction. The *desired* out-of-plane steering profile can also be very far from the orbit normal (Figs. 8 and 9 of the present application). The satellite has onboard apparatus, including attitude sensors and actuators comprising the attitude determination and control systems (page 6 of the present application), to execute any desired thruster, solar array and attitude steering profile.

Table 1 summarizes the differences between the present application and the Porte et al. teachings. The restrictive in-plane thrusting direction of Porte et al. must be normal to the earth direction. Those skilled in the art know that for the elliptical subsynchronous transfer orbit described by Porte et al. (page 2, column 2, paragraph 1) this thrust will tend to raise both *apogee* and perigee. Thus Porte et al. must stop the EPS phase prior to reaching the geosynchronous target orbit. Porte et al. state "The EPS is then operated continuously on an elliptical orbit with increasing semi-major axis until apogee reaches the geosynchronous altitude. The circularization is then obtained with CP." (Chemical Propulsion). In fact, because EP must terminate prior to completing circularization the inclination change must also be completed with CP firing (Strategy 3, page 6, column 1, section 3.4.3, paragraph 1).

The teachings of the present invention place no such restrictions on the EOR process. Apogee altitude can be above geosynchronous and can increase, remain essentially constant or decrease depending upon what is best for the EOR mission.

Comparison Item	**Gelon et al.** **Application/Control Number 09/328,911**	**Porte et al.** **AIAA 92-1955**
Propulsion	Electric	Electric
Attitude	Steered	Steered
In-plane thrust attitude	Steered around the orbit to optimally raise perigee and raise or lower apogee (Variable thrust direction that is best for each mission phase)	Maintained normal to the earth-satellite direction, but "oriented" along the direction of velocity to always raise perigee and apogee
Out-of-plane thrust attitude	Steered to optimally reduce inclination (near zero only near the anti-nodes) Can have large slew angle and still keep solar arrays normal to the sun	Slewing around the earth direction around the line of nodes Cannot have large slew angle or else solar arrays will not be oriented to the sun
Thruster Alignment to Spacecraft	Any thruster orientation angle to solar array rotation axis (including normal) Can use same thruster for both EOR and on-orbit stationkeeping	Thruster is normal to solar array rotation axis only (implied by the constraints stated in paper) Cannot use same thruster for both EOR and on-orbit stationkeeping
Solar array Orientation	Solar array rotation axis steered to be aligned with normal to sun direction ♦ Compatible with slewing to produce out-of-plane thrust ♦ Solar array rotation axis is not required to be aligned with the orbit normal and the thruster is not required to be mounted normal to the solar array rotation axis	Solar array rotation axis *stated* as kept aligned with the orbit normal ♦ Incompatible with slewing to produce out-of-plane thrust ♦ If solar array rotation axis is allowed to slew it will move from being aligned with the orbit normal and as a result the solar arrays cannot, in general, be kept oriented to the sun (unless slew angle is very small and the sun is restricted to be in or very near the orbit plane)
Attitude Reference	Sensors and actuators to allow steering of thrust in any direction	IR Earth Sensor (IRES) with limited bias capability
Continuous Thrust	Yes	Yes (Strategy 2 and 3)
Thrust at perigee	Yes	Yes
Apogee and Perigee of *final* EOR orbit (nominal)	Apogee = Geosynchronous Perigee = Geosynchronous No restrictions on thrust direction permits the final desired orbit to be obtained (could have a final chemical touchup)	Apogee = Geosynchronous Perigee = *Sub*-synchronous Severe restrictions on firing direction forces the EOR process to stop before perigee reaches its geosynchronous target because apogee reaches there first
Inclination of initial and final EOR orbits	Initial = Above target orbit (i > zero deg) Final = Equal to target orbit (i = zero deg) Touchup for final orbit and guidance errors could be done with chemical or electric	Initial = Above target orbit (I > zero deg) Final = Above target orbit (i > zero deg) Complete inclination removal using Chemical Propulsion Subsystem

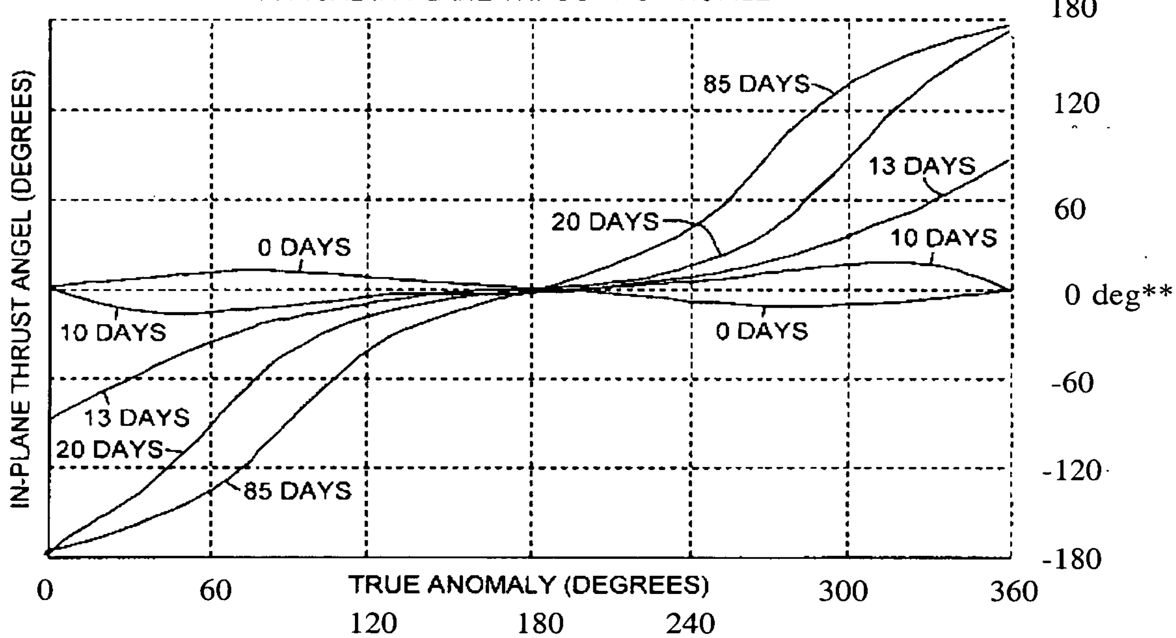
Fig. 7


15
14
13
ORBIT AT
0 DAYS
PROJECTION ON ORBIT PLANE - THE LENGTH OF EACH LINE IS PROPORTIONAL TO THE IN-PLANE THRUST (SHORTER LINES MEAN MORE OUT-OF-PLANE THRUST)

5/8

Fig. 8

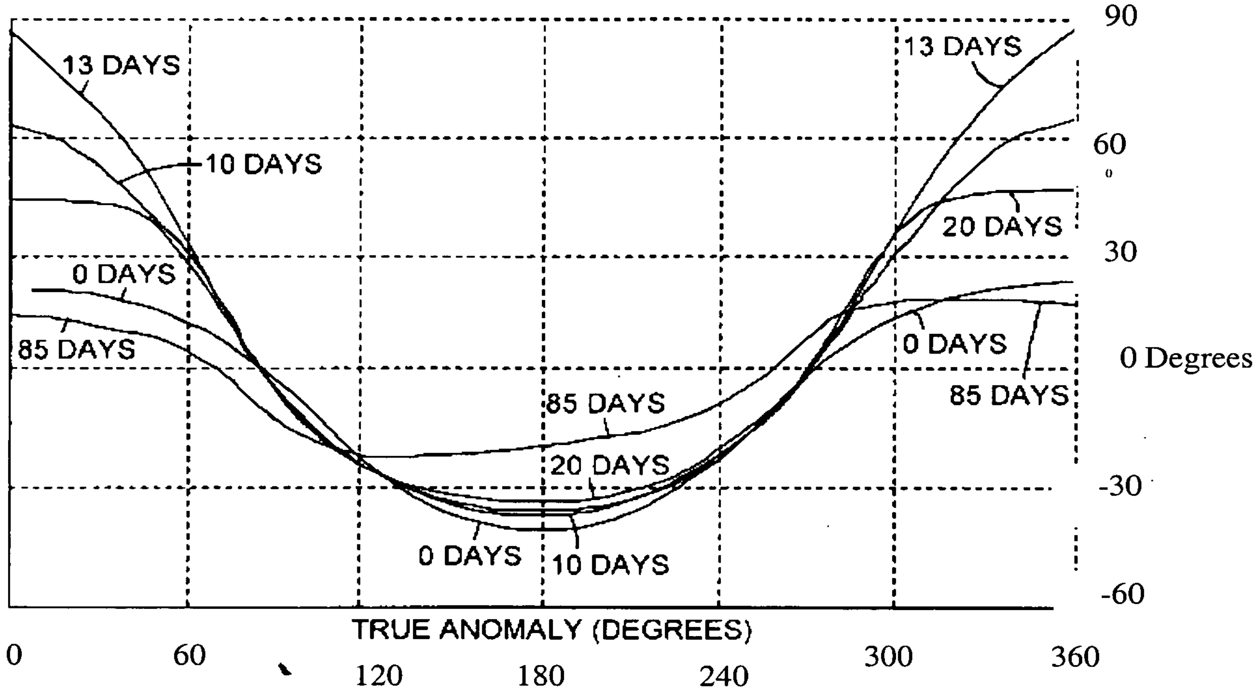
TYPICAL IN-PLANE THRUSTING PROFILE



** 0 degrees has in-plane thrust along normal to earth direction (along velocity at perigee and apogee)

Fig. 9

TYPICAL OUT-OF-PLANE THRUSTING PROFILE



A key aspect of the present invention is to keep the sun on the solar array while not maintaining an earth facing panel and delivering thrust in an optimal direction to minimize fuel usage and maximum spacecraft (payload) mass. The present invention delivers more delta v by thrusting in the optimum direction to maximize the mass of payload delivered into geosynchronous orbit.

In view of the above, and with regard to amended Claim 1, it is respectfully submitted that the Porte et al. paper does not disclose or suggest "firing the electric propulsion thrusters to raise the orbit of the spacecraft from the orbit achieved by the chemical propulsion thrusters firing step to near geosynchronous orbit by steering the thrust vector both in-plane and out-of-plane while rotating the spacecraft body and steering the solar array to maintain the sun's illumination on the solar array while not maintaining the solar array rotation axis aligned with the orbit normal and <u>while not maintaining an earth facing panel</u>", as is recited therein. [Emphasis added] The Porte et al. paper does not disclose or suggest this aspect of the present invention.

Therefore, it is respectfully submitted that the invention recited in Claim 1 is not disclosed or suggested by the Porte et al. paper. Accordingly, withdrawal of the Examiner's rejection and allowance of Claim 1 are respectfully requested.

With regard to amended Claim 23, it is respectfully submitted that the Porte et al. paper does not disclose or suggest "firing the electric propulsion thrusters to raise the orbit of the

spacecraft from the orbit achieved by the chemical propulsion thrusters firing step to near geosynchronous orbit by steering the thrust vector both in-plane and out-of-plane while rotating the spacecraft body and steering the solar array to maintain the sun's illumination on the solar array while not maintaining the solar array rotation axis aligned with the orbit normal and <u>while not maintaining an earth facing panel</u>", as is recited therein. [Emphasis added] The Porte et al. paper does not disclose or suggest this aspect of the present invention.

Therefore, it is respectfully submitted that the invention recited in Claim 23 is not disclosed or suggested by the Porte et al. paper. Accordingly, withdrawal of the Examiner's rejection and allowance of Claim 23 are respectfully requested.

Claims 2-14, 16, and 24-29 are considered patentable based upon the allowability of Claims 1 and 23. Withdrawal of the Examiner's rejection and allowance of Claim Claims 2-14, 16, and 24-29 are respectfully requested. Additional discussion of selected dependent Claims is presented below.

With regard to Claim 2, it recites that the thrust vector is substantially normal to the axis of the solar array and the sun is maintained substantially normal to the solar array. The comparison of present invention and this paragraph from the Porte et al. paper was described with regard to paragraph "1." above.

In Porte et al. the *thruster* is oriented normal to the axis of the solar array so the thrust vector is also normal to the rotation axis of the solar array. One panel is kept facing the earth. However in Porte the sun is, in general, *cannot* be normal to the solar array. Two cases are possible:

(a) Thrust vector in plane *only:* Porte et al. state that the solar array rotation axis must be aligned normal to the orbit normal. The sun can be normal to the solar array only if the satellite-sun direction is also in the orbit plane (i.e. along the line of nodes). As the earth moves around the sun this geometry cannot be maintained (~1 degree/day of motion in inertial space). After about 90 days of orbit raising the sun will actually be at its maximum out of plane position (along the anti-nodes). No inclination change is possible with the thrust vector in the orbit plane.

(b) Thrust vector contains *some* normal to the orbit plane component: If the thrust vector is out of plane then the solar array rotation axis can no longer be kept aligned with the orbit normal. If the spacecraft is slewed out of plane while maintaining an earth-facing panel then the sun *cannot* be normal to the solar array.

The present application discloses a method of steering to keep the sun normal to the solar arrays when the *thruster* is aligned normal to the solar array rotation axis independent of the direction in inertial space of the thrust vector. The thrust vector can be in-plane, out-of-plane or somewhere in between. Note that Claim 1 has been modified to clearly eliminate the restrictive steering directions described by Porte et al.

It is also respectfully submitted that Claim 2 is allowable based upon the allowability of Claim 1. Accordingly, withdrawal of the Examiner's rejection and allowance of Claim 2 are respectfully requested.

With regard to Claims 3, 25, and 26, they essentially recite that the thrust vector is not normal to the axis of the solar array and the thrust vector is steered to provide sufficient solar array power to perform maneuvers and minimize propellant usage and/or time to achieve final orbit. The Porte et al. paper discloses that the *thruster* is normal to the solar array rotation axis (page 2, paragraph 3 in section 3.2) and thus any delivered thrust vector is normal to the solar array rotation axis. Porte et al. do *not* disclose any conditions where the thruster is not oriented normal to the solar array rotation axis. This is also addressed in the amendments made to Claims 1 and 23.

Porte et al. do say (on page 6, column 1, section 3.4.3, paragraph 1) that the "EPS out-of-plane orientation must be such that the inclination decreases from i_1 down to i_2 during the electric transfer." This statement does *not* say that the thrust vector is *not* normal to the axis of the solar array. If the solar array axis is maintained normal to the orbit plane (page 2, paragraph 3 in section 3.2) a *fixed* thrust direction cannot change inclination even if the EPS thruster is oriented out-of-plane. On one side of the orbit (around the ascending node) inclination would decrease but on the other side of the orbit (around the descending node) inclination would increase again.

Porte et al. describe changing inclination by "slewing the spacecraft about the earth direction around the orbit nodes."(page 5, column 2, paragraph 1) Under these conditions the EPS can deliver components of thrust that are out-of-plane and can remove inclination provided the "thrust slewing" is in opposite directions at each node. But as described above (see 1. and 2.) the desire for large out-of-plane components of thrust (large slew angles) will result in insufficient solar power being available to perform maneuvers. The sun will be far off the normal to the solar arrays unless both the in-plane thrust angle and the slew magnitude are severely restricted.

Furthermore, in Porte et al., the steering profile does not minimize propellant use. Porte et al. limit the in-plane thrusting to take place along the normal to the earth-satellite direction which is clearly sub-optimal for fuel usage (see for example, Fig. 8 enclosed herewith). Certainly thrusting along the velocity, at times, will raise perigee more rapidly. As described above with regard to 1., at times, it may even be optimal to thrust in a direction nearly opposite to the velocity. This limitation on thrust direction does not result in minimum propellant usage and/or time to achieve final orbit.

Claims 3, 25, and 26 are also considered patentable based upon the allowability of Claims 1 and 23. Accordingly, withdrawal of the Examiner's rejection and allowance of Claims 3, 25, and 26 are respectfully requested.

With regard to Claim 5, the Porte et al. paper does not disclose that the transfer orbit is supersynchronous. In fact, due to the restrictive nature of the allowable thrusting directions EPS continues until "apogee reaches the geosynchronous altitude."(page 2, column 2, paragraph 1) the present specification discloses that the optimum EOR profile may desire that apogee rises above geosynchronous and then return again to geosynchronous at the conclusion of the transfer phase. It is respectfully submitted that there is no mention of a supersynchronous orbit contained in the Porte et al. paper. In particular, page 2, column 1 cited by the Examiner does not mention the terms "supersynchronous" or "supersynchronous orbit". Therefore, it is respectfully submitted that the invention recited in Claim 5 is not disclosed or suggested by the Porte et al. paper.

Accordingly, withdrawal of the Examiner's rejection and allowance of Claim 5 are respectfully requested.

With regard to Claims 11 and 28, it is respectfully submitted that there is no mention at page 5, column 1 regarding firing the electric propulsion thrusters to compensate for the disturbances. The term "disturbance" is not used in the Porte et al. paper.

With regard to Claims 14, 15 and 16 it is respectfully submitted that there is no mention at page 2, column 2 regarding a "throttled-back mode", "initially turning off one or more of a plurality of electric thrusters turned off so they can be turned on at a later time to give increased acceleration capability in the presence of disturbances experienced by the spacecraft", or "coast periods". These concepts and terms are not mentioned in the Porte et al. paper. It is not clear what the Examiner is referring to.

Again, dependent Claims 2-14, 16, and 24-29 are considered patentable based upon the patentability of Claims 1 and 23 from which they depend. Therefore, withdrawal of the Examiner's rejection and allowance of Claims 2-14, 16, and 24-29 are respectfully requested.

Claims 17-22 were rejected under 35 U.S.C. 103(a) as being unpatentable over the Porte et al. paper in view of US Patent No. 6,032,904 issued to Hosick et al. The Hosick et al. patent is cited as disclosing "using momentum wheels in figure 1c, pointing the thrust or differential thrust away from the center of mass to provide control torque and raise the orbit in figures 14 and 15; or using thruster on the north and south side of the spacecraft to decrease the duration of the orbit raising phase in figure 11.

It is respectfully submitted that, as the Examiner admitted, the Porte et al. paper does not disclose or suggest the concepts purportedly disclosed by the Hosick et al. patent. The Porte et al. paper is not concerned with these issues because it only addresses the three specifically disclosed orbit raising strategies and does not discuss any details of implementation. It is respectfully submitted that combining the teachings of the Hosick et al. patent with those of the Porte et al. paper has been done using hindsight reconstruction and is speculative. There must be some disclosure or suggestion contained in the cited references that would support their combination. Such a disclosure or suggestion is not present in either reference that would support combining their teachings.

For example, the Porte et al. paper contains no discussion regarding adjusting attitude steering profiles, or a plurality of momentum wheels, or pointing thrust vectors away from the center of mass of a spacecraft, or gimbals that are used to provide control torque, or differentially throttling one or more thrusters to provide control torque, or the use of thrusters to increase the effective thrust and decrease the duration of the electric orbit raising phase. While the Hosick et al. patent discloses the use of thrusters and gimbals to provide for orbit raising, north-south station keeping, and selective unloading of momentum wheels, it is respectfully submitted that these aspects are not relevant to the express teachings contained in the Porte et al. paper. The mere fact that orbit raising, north-south station keeping, and selective unloading of momentum wheels may be controlled by the use of thrusters and gimbals in the system disclosed in the Hosick et al. patent

does not by itself imply that these teachings are applicable to the orbit raising strategies discussed in the Porte et al. paper, since the spacecraft and systems are not necessarily the same nor do they necessarily operate in the same way, and particularly, since there are no implementation details disclosed in the Porte et al. paper.

Dependent Claims 17-22 are also considered patentable based upon the patentability of Claim 1 from which they depend. Therefore, withdrawal of the Examiner's rejection and allowance of Claims 17-22 are respectfully requested.

The prior art heretofore made of record and not relied upon is considered pertinent to Applicant's disclosure to the extent indicated by the Examiner.

Attached hereto is a marked-up version of the changes made to claims by the present amendment. The attached page is captioned "Version with markings to show changes made."

In view of the above, it is respectfully submitted that Claims 1-29 are not anticipated by, nor are they obvious in view of, the cited references, taken singly or together, and are therefore allowable. Accordingly, it is respectfully submitted that the present application is in condition for allowance. Reconsideration of this application and allowance thereof are earnestly solicited.

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE CLAIMS

The following Claims have been amended in the manner indicated.

1. (Amended) A method for raising a spacecraft launched into a transfer orbit about the Earth from the transfer orbit to a geosynchronous orbit, comprising the steps of:

launching a spacecraft having chemical and electric propulsion thrusters and a solar array;

firing the chemical propulsion thrusters at apogees of intermediate orbits, starting from the transfer orbit initiated by the launch vehicle, to successively raise perigees of the orbit until the spacecraft perigee substantially clears the Van Allen radiation belts, and where the semi-major axis of the intermediate orbit is substantially less than the semi-major axis of [the] a final orbit, and where the inclination of the intermediate orbit is substantially greater than the inclination of the final orbit;

firing the electric propulsion thrusters to raise the orbit of the spacecraft from the orbit achieved by the chemical propulsion thrusters firing step to near geosynchronous orbit by steering the thrust vector both in-plane and out-of-plane while rotating the spacecraft body and steering the solar array to maintain the sun's illumination on the solar array <u>while not maintaining the solar array rotation axis aligned with the orbit normal and while not maintaining an earth facing panel</u>; and

firing selected ones of the chemical and electric propulsion thrusters to achieve final geosynchronous orbit.

23. (Amended) A system for raising a spacecraft launched into a transfer orbit about the Earth from the transfer orbit to a geosynchronous orbit, comprising:

a spacecraft comprising chemical and electric propulsion thrusters and a solar array;

a processor onboard the spacecraft for:

firing the chemical propulsion thrusters at apogees of intermediate orbits, starting from the transfer orbit initiated by the launch vehicle, to successively raise perigees of the orbit until the spacecraft perigee substantially clears the Van Allen radiation belts, and where the semi-major axis of the intermediate orbit is substantially less than the semi-major axis of [the] a final orbit, and where the inclination of the intermediate orbit is substantially greater than the inclination of the final orbit;

firing the electric propulsion thrusters to raise the orbit of the spacecraft from the orbit achieved by the chemical propulsion thrusters firing step to near geosynchronous orbit by steering the thrust vector both in-plane and out-of-plane while rotating the spacecraft body and steering the solar array to maintain the sun's illumination on the solar array <u>while not maintaining the solar array rotation axis aligned with the orbit normal and while not maintaining an earth facing panel</u>; and

firing selected ones of the chemical and electric propulsion thrusters to achieve final geosynchronous orbit.